CalDet Update: Muon Analysis

Chris Smith
UCL-London

The MINOS Collaboration Meeting

at Caltech

January 3-6, 2002

Update on Muons at CalDet

MINOS Collaboration Meeting

January 2002

Contents:

- Introduction

- Event Selection

- Muon Energy Spectra and Fits

- Results

- Comparison with Data before HV Change

- Timing

- Stopping Muons

Introdction

- Objective is to produce a set of numbers corresponding to energy deposited by a muon for each strip (and each side) for detector calibration

- From test-beam runs, muons are selected and energy deposits are histogrammed for each channel

- Muon energy spectra are fitted to give a value corresponding to peak of Landau for each strip

Data Used

- Previously analysed 2 GeV runs from before HV change to obtain a set of MIP numbers for calibration

- Latest data: 2.5 GeV run from after HV change

Event Selection in Beam Data

Look at each event in turn and apply the following selection criteria:

Cuts:

- Total number of hits in an event >= 16

- Number of hits in a "track" >= 4 (in both orientations =>
  minimum track length = 8 planes)

- Along the path of a track, no more than 2 hit strips in 5, per plane

- Angle of track must be < 10 degrees in all 4 views wrt beamline

- Only hits in a track seen on both sides are accepted

To find a "track":

Find a hit in strip n, look for another hit in the next plane (of same
orientation) within n+/-m strips, etc...

Stop tracking if more than 2 hits are seen in a block of n+/-m strips
or if 2 hits within a block occur in 2 consecutive planes
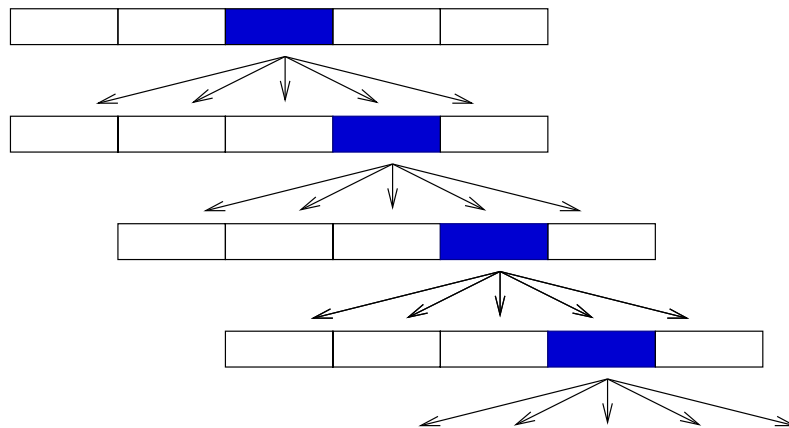
Cut	Approx. No. of events	% of total	% of previous
None	3,700,000	100	100
>=16 hits	3,250,000	87.8	87.8
4 Hit Track (even planes)	1,114,000	30.1	34.3
4 Hit Track (odd planes)	1,215,000	32.8	37.4
Track in both even and odd	761,000	20.6	65.3
<10 degrees	350,000	9.5	46.0

Table 1: Selection Statistics from a 2 GByte Beam Run. Typically $\sim$ 9-10% of events pass all cuts.
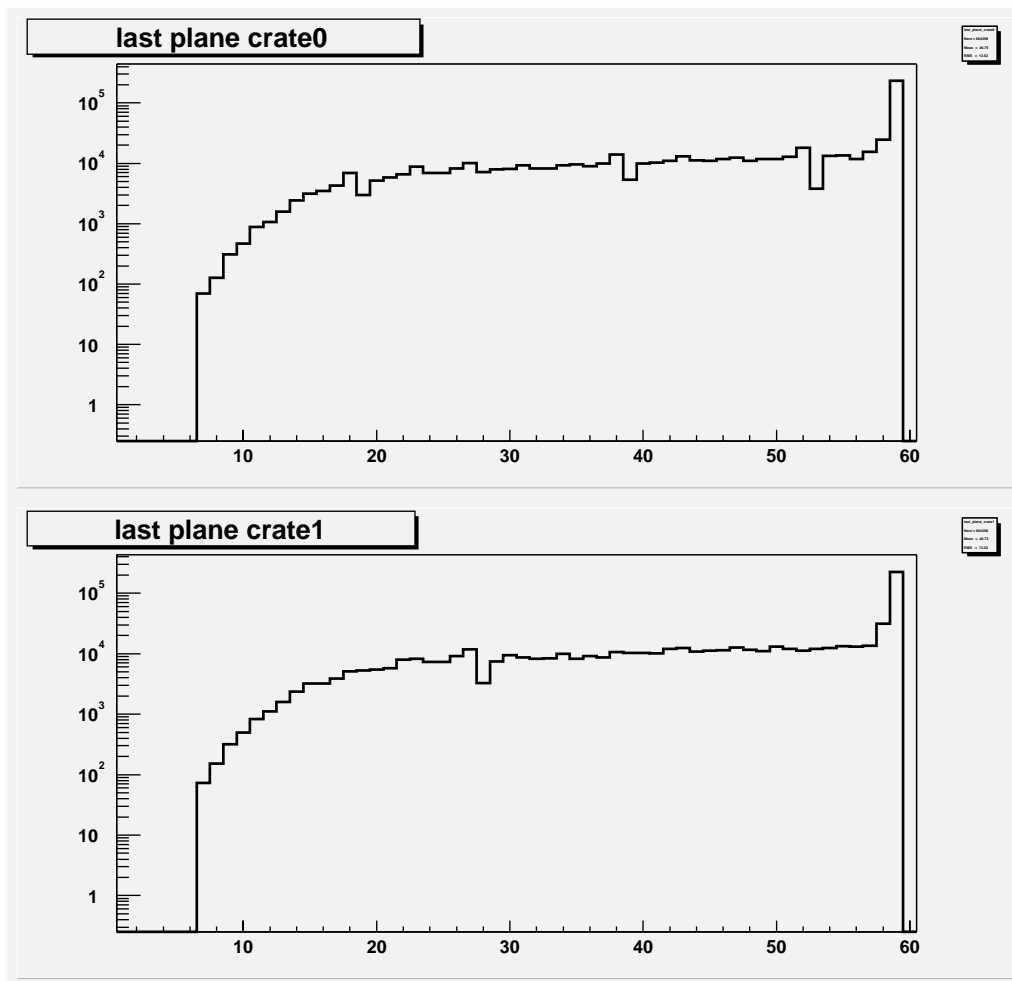
Angles of Muon Events from Beam
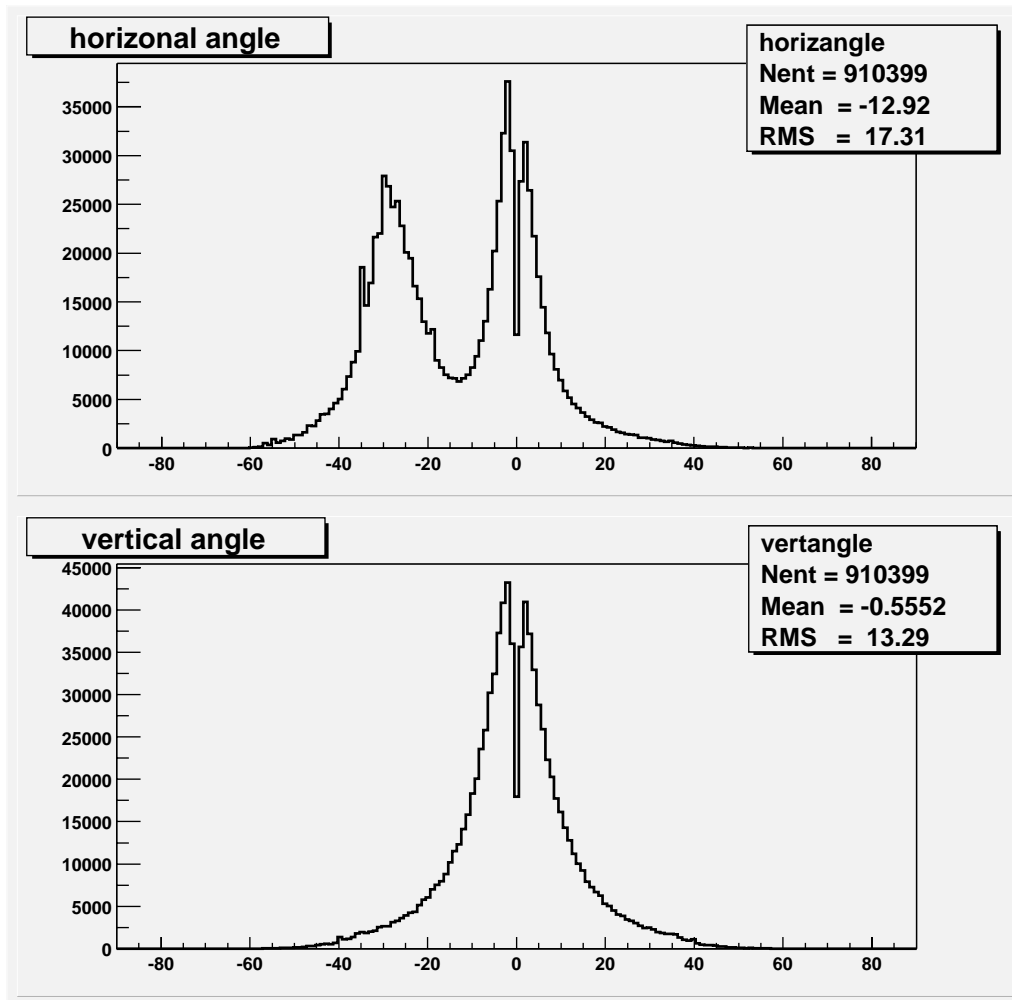
Peaks around 0 as expected in both horizontal and vertical angle.
Secondary peak in horizontal angle corresponding to muons from
PS

Last Plane Hit/Track Length

Looking at the last plane hit in each selected event:

Stopping distance for 2.5 GeV muons peaks at > plane 60

(Compare with 2 GeV muons: last plane distribution peaks at plane 55)

Fitting Function

Want to Approximate:

$$L \otimes P = \int L(\lambda, \mu, \sigma).P(n, \lambda)d\lambda$$

- Use the ROOT adapted CERNLIB routine for Landau

- Simulate integral with summation:

$$L \otimes P \approx N \sum_{\lambda=1}^{20} L(\lambda.s, \mu, \sigma).P(n, \lambda.s)$$
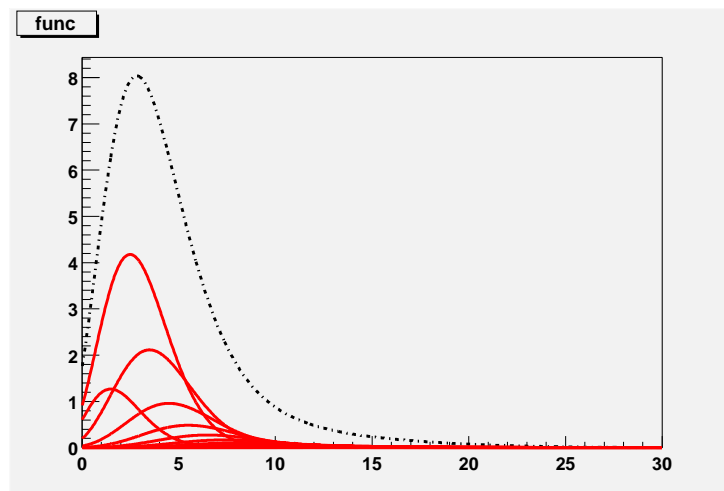
  Where the basic units used are NPEs and s is a scale factor
  which depends on the range of the histogram

- Therefore need 3 fit parameters: μ and σ in NPEs from Landau,
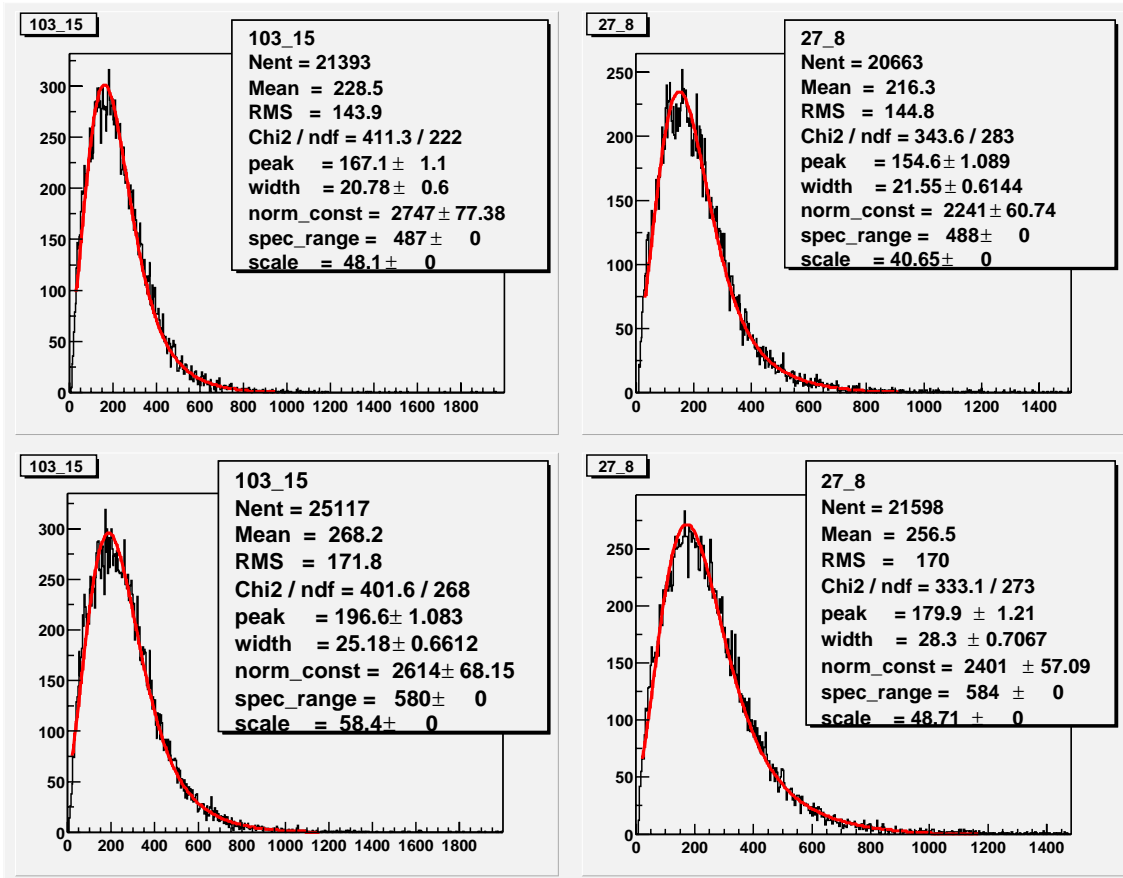 and a normalisation constant, N

Example
with:

$\mu = 3$
$\sigma = 0.5$
$N = 100$
$s = 20$

Examples of Fits

Histograms are rebinned and fit using the function above. Examples:

103_15
Nent = 21393
Mean = 228.5
RMS = 143.9
Chi2 / ndf = 411.3 / 222
peak   = 167.1 ± 1.1
width   = 20.78 ± 0.6
norm_const = 2747 ± 77.38
spec_range = 487 ±   0
scale   = 48.1 ±   0

27_8
Nent = 20663
Mean = 216.3
RMS = 144.8
Chi2 / ndf = 343.6 / 283
peak   = 154.6 ± 1.089
width   = 21.55 ± 0.6144
norm_const = 2241 ± 60.74
spec_range = 488 ±   0
scale   = 40.65 ±   0

103_15
Nent = 25117
Mean = 268.2
RMS = 171.8
Chi2 / ndf = 401.6 / 268
peak   = 196.6 ± 1.083
width   = 25.18 ± 0.6612
norm_const = 2614 ± 68.15
spec_range = 580 ±   0
scale   = 58.4 ±   0

27_8
Nent = 21598
Mean = 256.5
RMS = 170
Chi2 / ndf = 333.1 / 273
peak   = 179.9 ± 1.21
width   = 28.3 ± 0.7067
norm_const = 2401 ± 57.09
spec_range = 584 ±   0
scale   = 48.71 +   0

Fit Summaries

For Clear Fibre Readout:
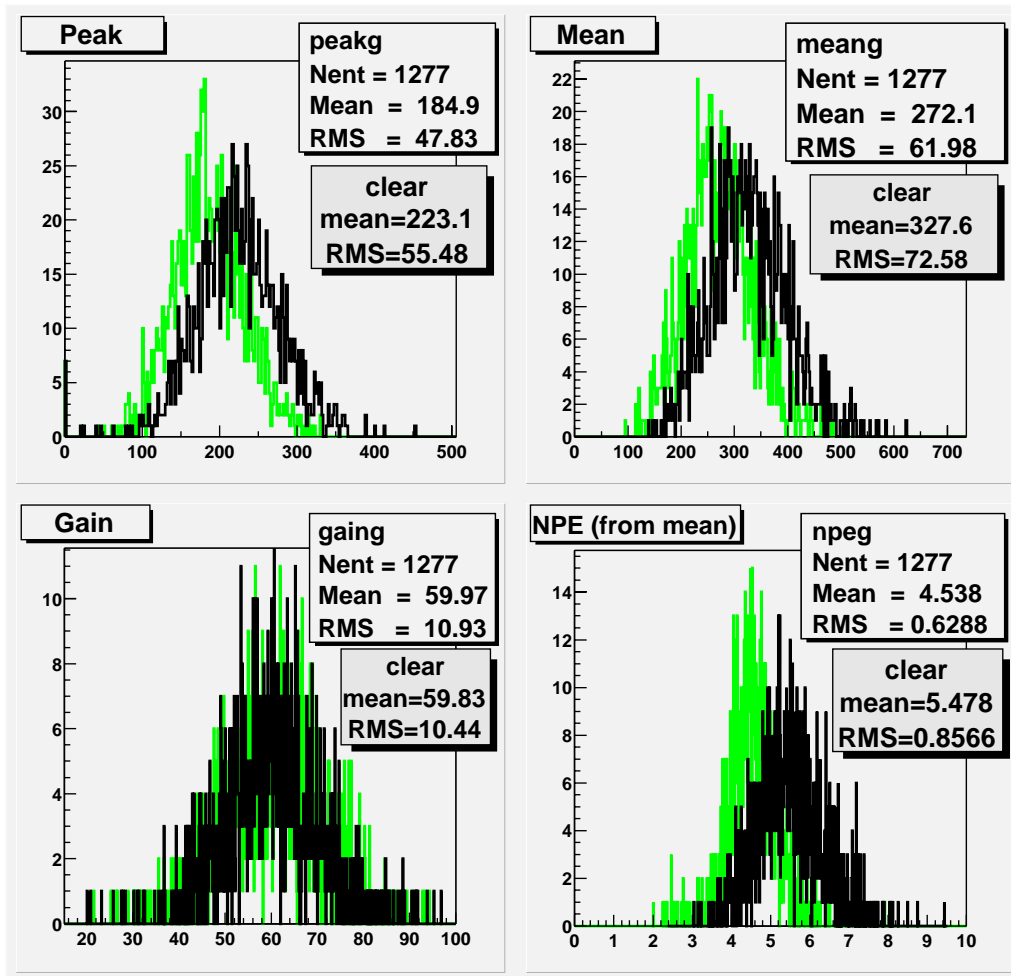
Clear Mean MIP value = 5.45 +/- 0.04

Green Mean MIP value = 4.52 +/- 0.02

From Peaks:

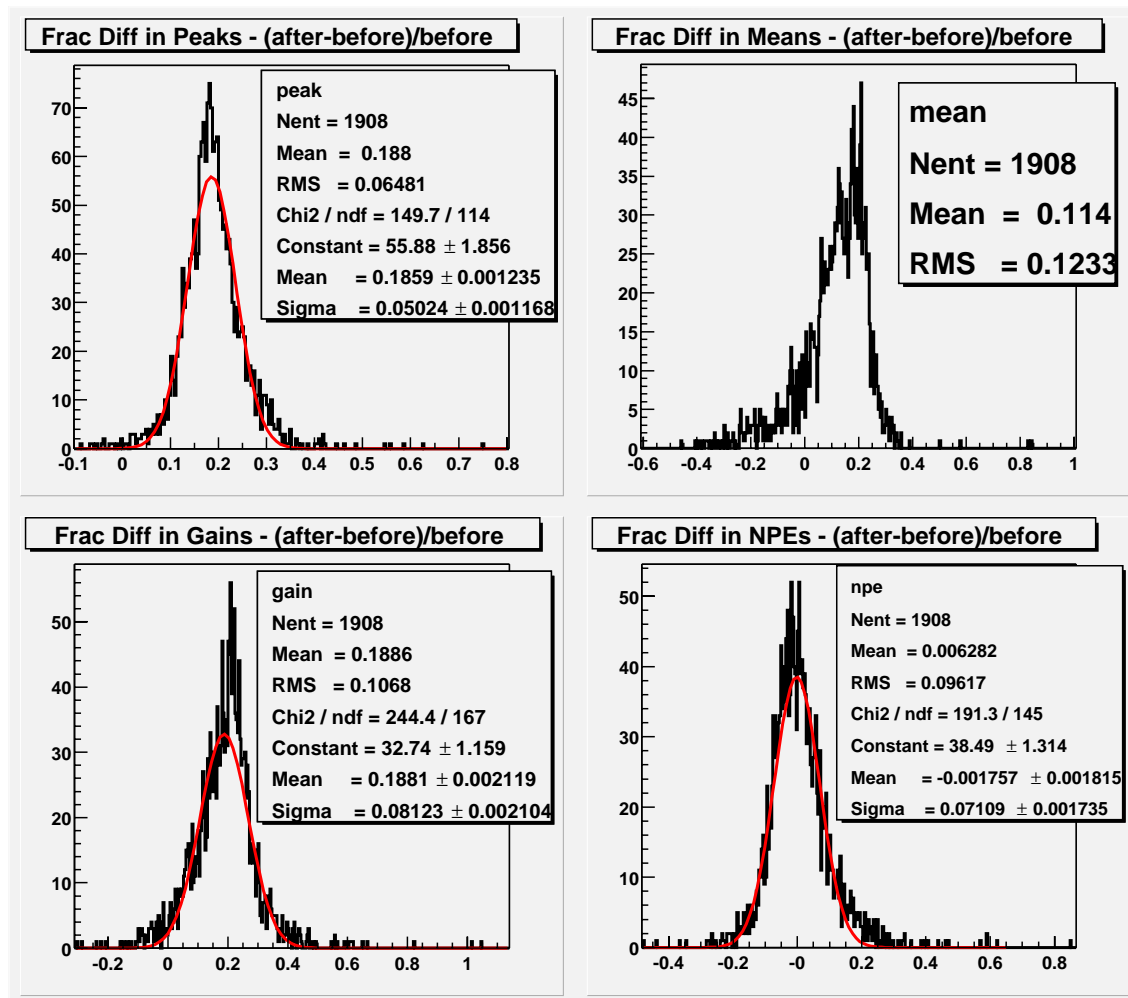Clear Mean MIP value = 3.75 +/- 0.02

Green Mean MIP value = 3.13 +/- 0.01

Stability of MIPs with HV Change

Compare MIP values from before and after HV change

Only compare values for plane<50 (for 2 GeV muons, stopping plane = 55)

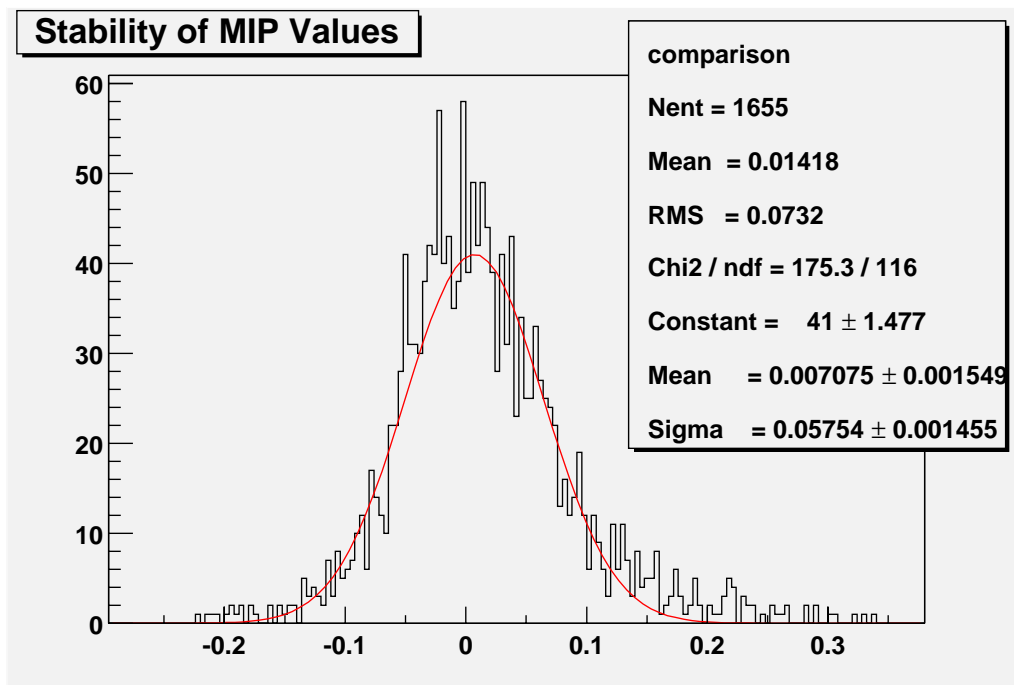Expect the MIP values, in terms of NPEs, to be independent of HV

Looking at peaks and gains: ~19% increase after HV change

Looking at MIP values: mean = -0.002 +/- 0.002

Stability of MIP Values Over Time

Comparing two runs collected a month apart

Look at fractional difference in peak positions for all (possible) channels:

Stability of MIP Values

comparison

Nent = 1655

Mean = 0.01418

RMS   = 0.0732

Chi2 / ndf = 175.3 / 116

Constant =   41 $\pm$ 1.477

Mean   = 0.007075 $\pm$ 0.001549

Sigma   = 0.05754 $\pm$ 0.001455

mean = 0.007 +/- 0.002

4 sigma away from zero => $\sim$1% shift in MIP values over one month
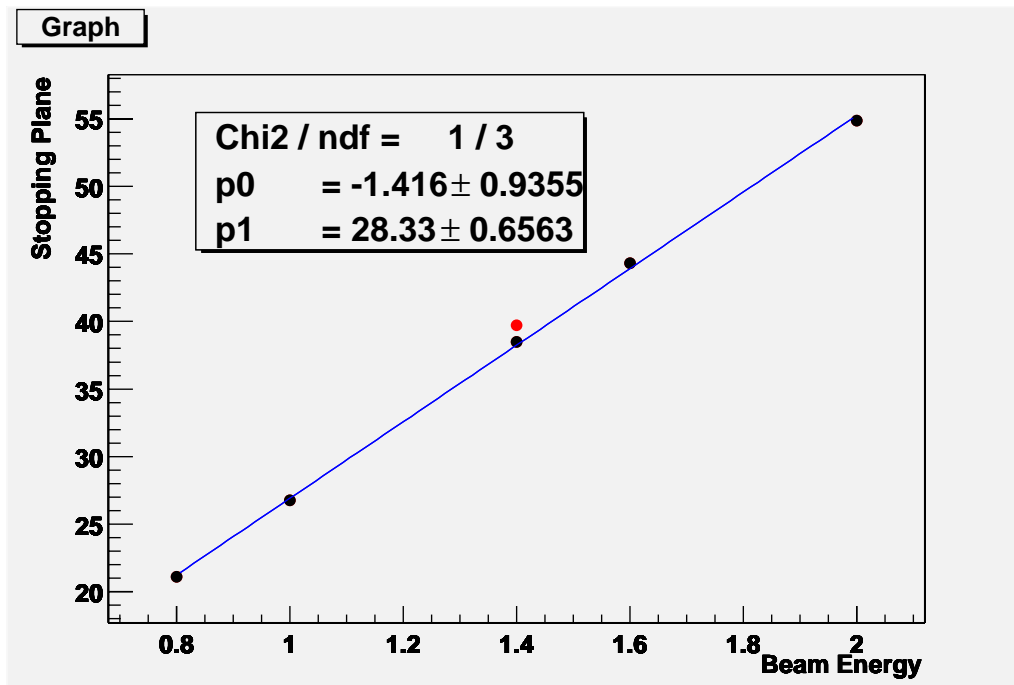
Stopping Muons

- To understand energy loss as a function of muon energy, look at 5 runs with beam energies 0.8, 1, 1.4, 1.6 and 2 GeV

- Know that the most energetic muons in a run have the beam energy. Need to select these muons for this measurement

- Look at stopping muons: histogram last plane hit in all muon events for each run
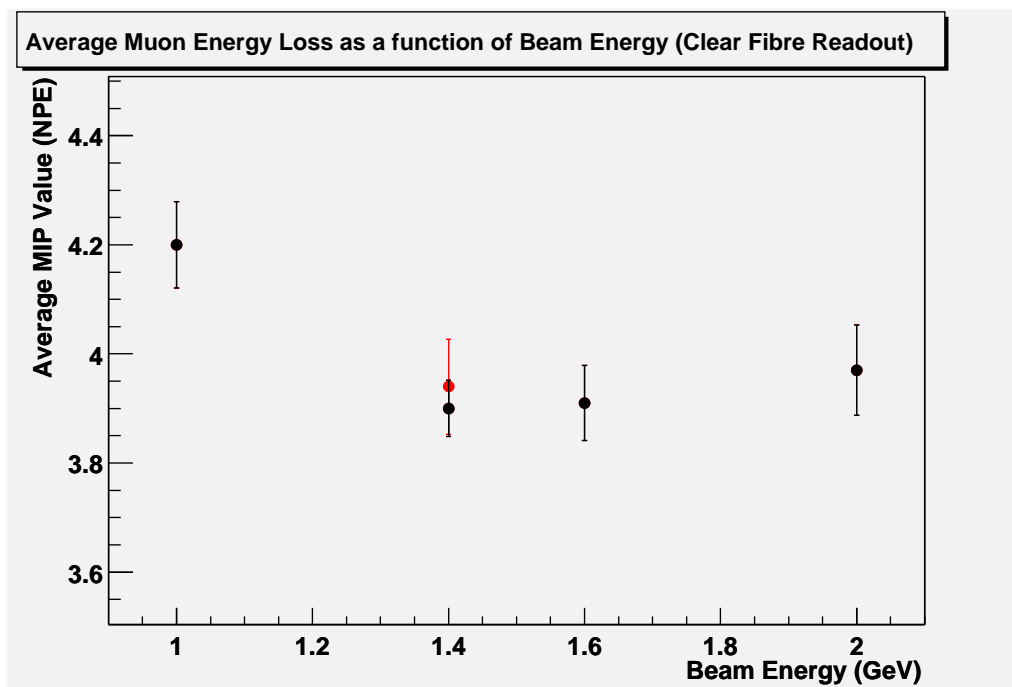
For 1 Gev Run:
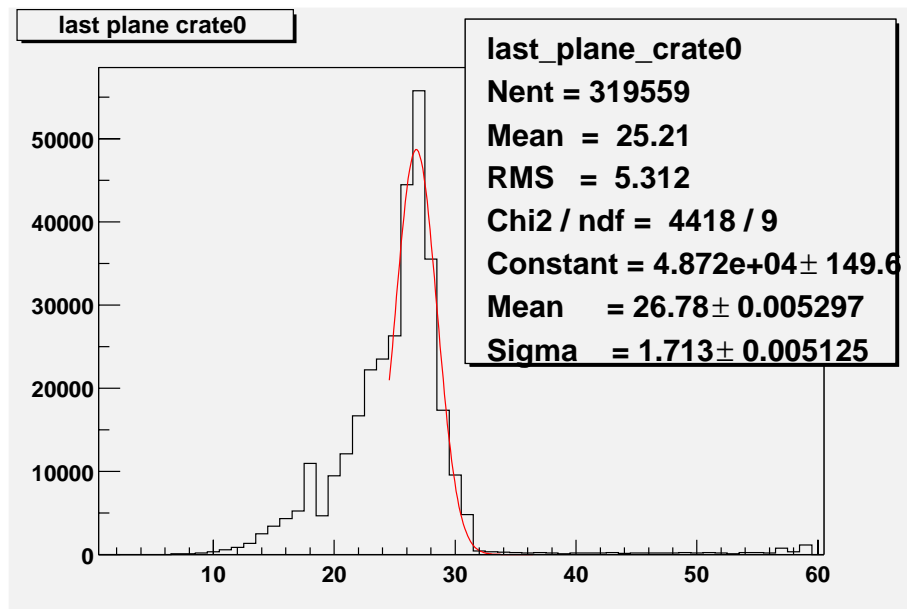
Stopping Muons

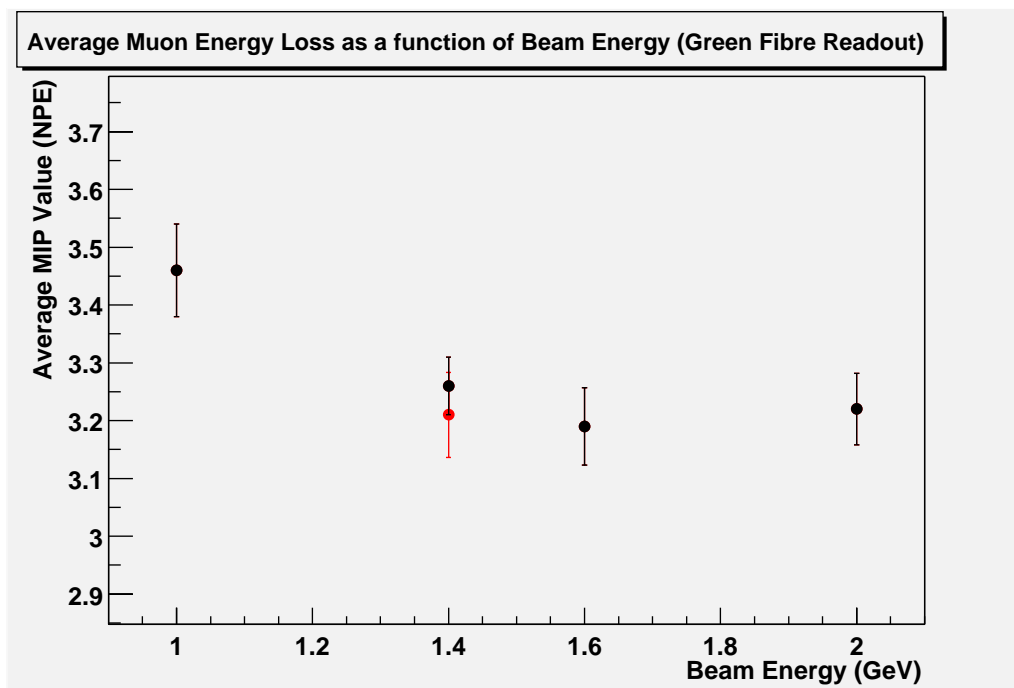Fit the peaks with Gaussian for each of the 5 beam energies and plot:

Stopping Muons

- Muons with maximum beam energy correspond to those in the peak

- Select only muons stopping in peak plane (+/- 1 plane) then fill and fit energy spectra as before

- Look at a strip in front 10 planes of the detector to find energy loss as a function of muon energy
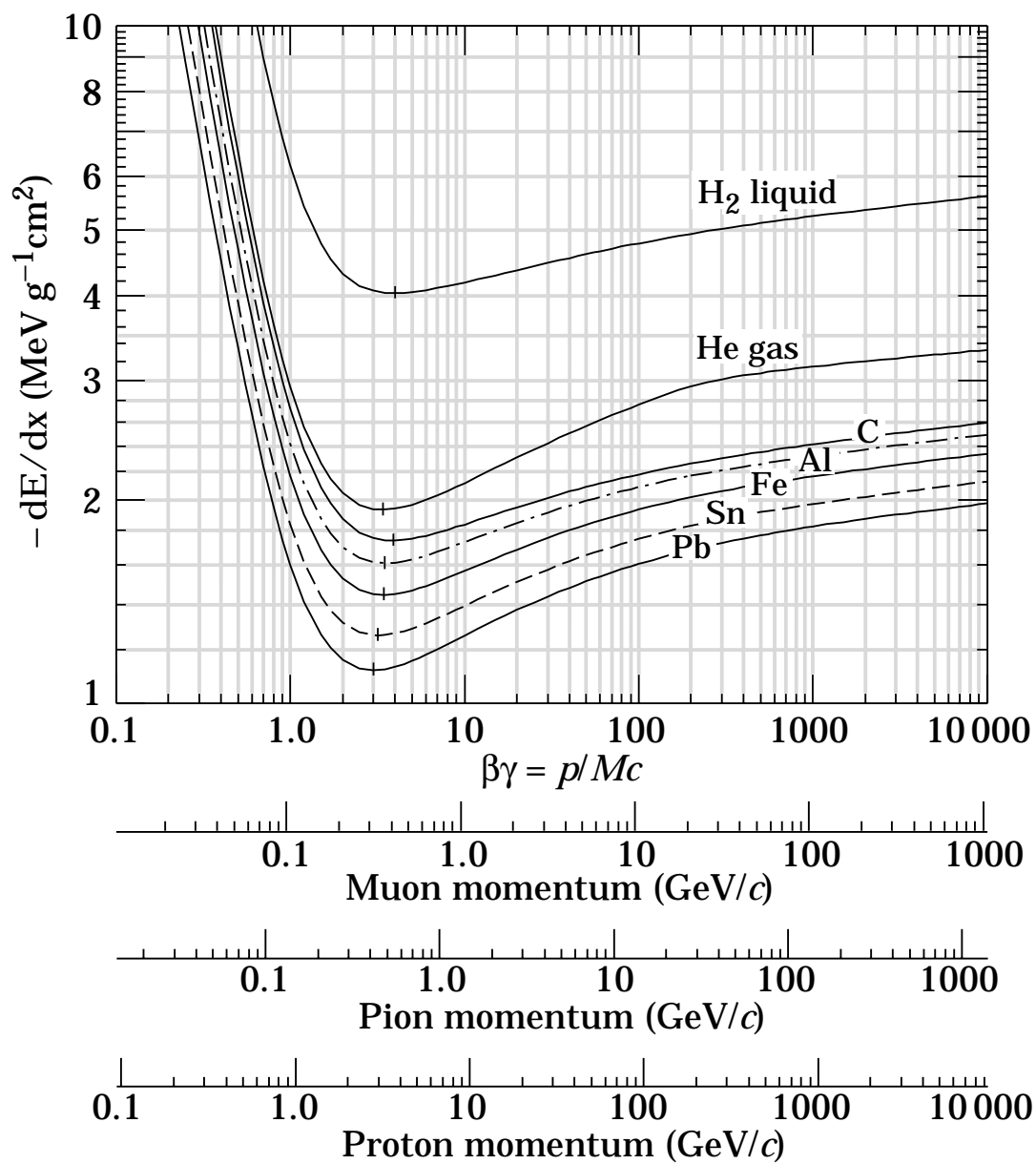
Clear Fibre Readout:

Average Muon Energy Loss as a function of Beam Energy (Clear Fibre Readout)

Stopping Muons

Green Fibre Readout:

Average Muon Energy Loss as a function of Beam Energy (Green Fibre Readout)

Stopping Muons

Bethe-Block:

Figure axes: $-dE/dx$ (MeV g^{-1}cm^2) versus $\beta\gamma = p/Mc$, with curves labeled H$_2$ liquid, He gas, C, Al, Fe, Sn, Pb. Additional momentum scales: Muon momentum (GeV/c), Pion momentum (GeV/c), Proton momentum (GeV/c).

Summary

- At 2.5 GeV, after HV change, mean MIP values are

  for clear: 5.45 pes

  for green: 4.52 pes

- MIP values are stable after HV Change (observed stability of MIP values over period of a month $\sim$0.7%)

- Possible to distinguish differences in energy loss at different beam energies. Need to understand higher energy loss at 1 GeV